THE USE OF VISCO-ELASTIC SELF-HEALING PIPELINE COATING

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ABSTRACT

Modern pipeline maintenance requires advanced corrosion prevention systems in order to prolong service cycles and to ensure reliable and sustainable operation features. Corrosion is one of those occurrences that will affect the safe and efficient running of the pipeline with the costs for shut down, lost production, product loss, environment contamination and loss of customer confidence running into millions of Euros.

Coating degradation problems that lead to the creation of a corrosion risk within the design life of a pipeline can mainly be attributed to one of the following causes: (1) an inappropriate specification for the coating material and/or coating process; (2) poor surface preparation and/or application; and (3) interaction with the operating environment like humidity, salts, winds, temperatures. Poor surface preparation and coating application continues to create problems with premature degradation, particularly loss of adhesion resulting in disbondment.

Besides the traditional applied protective coating systems which make use of chemical crosslink reactions for guaranteed corrosion protection, one might consider a totally contradictory approach in order to protect metal pipelines against the penetration of humidity and air.

The latest amorphous viscous elastic polymer pipeline coating technology having no specific chemical functionality exhibits new and unique aspects for sustainable corrosion protection. The new coating system is an extremely low cost innovative approach for rehabilitation and coating of field joints. This technology has been developed for use as the external coating of pipelines. This technology has been designed and tested specifically to fit the special field application requirements of buried oil and gas pipelines, and it exhibits properties that are contrary to traditionally specified systems and in most cases far exceeding them.[1] Properties and the tape-like application of the elastomer will be described. Possibilities to use elastomers as part of pipeline maintenance will be discussed. What are the limits and chances for materials that are not hard at all but tough enough to do the job?

Key words: visco-elastic coating, rehabilitation, subsea, polyisobutene, fieldjointcoating

RESUME

La maintenance moderne des canalisations requiert des systèmes avancés de prévention de la corrosion afin de prolonger les cycles d'entretien et de garantir des caractéristiques opérationnelles fiables et durables. La corrosion est l'une de ces circonstances qui affectera la sécurité et l'efficacité de l'exploitation de la canalisation ; les coûts relatifs à l'arrêt, à la production perdue, à la perte de produit, à la contamination de l'environnement et à la perte de confiance des clients se chiffreront en millions d'euros.

Des problèmes de dégradation du revêtement menant à l'apparition d'un risque de corrosion au cours de la durée de vie théorique d'une canalisation peuvent principalement être attribués aux causes suivantes : (1) des spécifications inadéquates du matériau et/ou processus de revêtement ; (2) une mauvaise préparation de la surface et/ou application et (3) une interaction avec l'environnement opérationnel (humidité, sel, vent, température). Une mauvaise préparation de la surface et une application inadéquate du revêtement continuent de causer des problèmes de dégradation prématurée, particulièrement une perte d'adhérence résultant en un décollement du revêtement.

Outre les systèmes traditionnellement appliqués de revêtement protecteur, qui recourent à des réactions de réticulation pour garantir la protection contre la corrosion, on peut considérer une approche totalement différente pour protéger les canalisations métalliques contre la pénétration de l'humidité et de l'air.

La dernière technologie de revêtement de canalisation par des polymères viscoélastiques amorphes sans effet chimique spécifique montre une nouvelle approche unique pour une protection durable contre la corrosion. Le nouveau système de revêtement est une approche innovante très bon marché de réhabilitation et de revêtement de joints sur le terrain. Cette technologie a été développée pour servir de revêtement externe de canalisations. Elle a été conçue et testée spécifiquement pour s'adapter aux exigences particulières des applications *in situ* sur des canalisations pétrolières ou gazières enterrées ; elle affiche des propriétés contraires aux systèmes traditionnellement spécifiés et les dépassent de loin dans la plupart des cas. Les propriétés et l'application de l'élastomère sous forme de ruban adhésif seront décrites. Les possibilités de recourir à des élastomères dans le cadre de la maintenance de canalisations seront discutées.
Quelles sont les limites et opportunités pour des matériaux qui ne sont pas durs du tout mais suffisamment résistants pour remplir la fonction ?

Mots-clés : revêtement viscoélastique, réhabilitation, sous-marin, polyisobutylène, revêtement de joint sur le terrain

ZUSAMMENFASSUNG

Moderne Pipelinewartung erfordert fortschrittliche Korrosionspräventionssysteme, um Wartungszyklen zu verlängern und zuverlässige und dauerhafte Betriebseigenschaften sicherzustellen. Korrosion ist eines der Vorkommnisse, die den sicheren und effizienten Betrieb der Pipeline beeinflussen. Dabei können sich die Kosten für Abschaltung, verlorene Produktion, Produktverluste, Umweltverschmutzung und verlorenes Kundenvertrauen mehrere Millionen Euro betragen.

Probleme durch Beschädigung der Beschichtung, die zu einem Korrosionsrisiko während der geplanten Lebensdauer einer Pipeline führen, können im Wesentlichen einer der folgenden Ursachen zugeschrieben werden. 1. Ungeeignete Spezifikation des Beschichtungsmaterials und/oder –prozesses; 2. Schlechte Vorbereitung des Untergrunds und/oder Aufbringung; 3. Interaktion mit der Betriebsumgebung, z. B. Feuchtigkeit, Salz, Wind, Temperatur. Mangelhafte Vorbereitung des Untergrunds und schlechter Beschichtungsauftrag sorgen weiterhin für Probleme mit vorzeitiger Degradierung, insbesondere den Verlust der Haftung, was zu einer Ablösung der Beschichtung führt.

Neben den herkömmlicherweise aufgetragenen Schutzbeschichtungssystemen, die chemisch vernetzte Reaktionen für garantierten Korrosionsschutz nutzen, könnte man auch einen völlig entgegenlaufenden Ansatz wählen, um Metallpipelines vor dem Eindringen von Feuchtigkeit und Luft zu schützen.

Die neueste Pipelinebeschichtungstechnologie mit amorphen viskoelastischen Polymeren, die keine bestimmten chemischen Funktionen haben, weisen neue und einzigartige Eigenschaften für nachhaltigen Korrosionsschutz auf. Das neue Beschichtungssystem ist ein extrem preisgünstiger, innovativer Ansatz für Reparatur und Beschichtung von Montageverbindungen. Diese Technologie wurde zur Verwendung als externe Beschichtung von Pipelines entwickelt. Sie wurde speziell dafür erdacht und geprüft, um zu den besonderen praktischen Anforderungen unterirdischer Öl- und Gaspipelines zu passen. Sie besitzt Eigenschaften, die im Gegensatz zu bisher spezifizierten Systemen stehen und sie in den meisten Fällen übertreffen[1]. Die Eigenschaften und die einem Klebeband ähnliche Anwendung des Elastomers werden beschrieben. Möglichkeiten der Verwendung von Elastomeren als Bestandteil der Pipelinewartung werden besprochen.
Was sind die Grenzen und Chancen für Materialien, die überhaupt nicht hart sind, aber robust genug, um dieser Aufgabe Herr zu werden?

Schlüsselwörter: Viskoelastische Beschichtung, Reparatur, unterseeisch, Polyisobuten, Beschichtung von Montageverbindungen.

INTRODUCTION

Modern pipeline maintenance and new construction require advanced corrosion protection systems in order to prolong service cycles and to ensure reliable and sustainable operation features. It is obvious that there are thousands of miles of corrosion protected pipelines which for decades have done their job. The question arises: “generally, is it correct and fair to mention that the existing pipeline corrosion protection systems do not fail.” This is a communication issue running around the globe. The question arises whether there is room for innovation in the field of pipeline corrosion protection if the statement mentioned before is correct.

Limits of Current Anti-Corrosion Systems

Looking deeper into pipeline maintenance projects, some failures and incidents can be found which even can be classified.

- mechanical damages
- soil creep and stress
- tenting or bridging at seam welds
- cracking
- poor application
- cathodic shielding
- osmosis and MIC problems

When diging deeper into this topic, more and more corrosion prevention failures can be found related to the chosen coating system. Having analyzed the various kinds of failures, one question comes up: “Why do anti-corrosion systems fail?”

In this paper, this topic is approached by proposing the following hypothesis: “Whenever an anti-corrosion system is applied, extrinsic properties are added.” These features are “attached to the system in order to fulfill the obvious requirements.

Many protective coatings rely on the function of cross-linking. In order to make the “coating system” work, a chemical crosslink reaction is required. The system adds mechanical stability and stiffness to the applied coating material. It is an extrinsic property of the applied coating.

For instance, regular anti-corrosion tapes require 50% overlap and machine application. Why you have to do the overlap? The tape itself will protect against corrosion, but are you sure that the “system” will work for long term protection? The overlap of the tape is an extrinsic property in order to improve the performance of the material at the edges.

<u>Another Example: Polyethylene-Shrinkable Sleeves.</u> It is definitely an extrinsic property when heat is applied to a shrink sleeve in order to reduce the distance between the protective layer and the substrate. It is an extrinsic property. What is the target for adding this extrinsic property? The answer is simple: The protective layer has to be hard, unbreakable, impermeable and durable.

Having analyzed the relevance of extrinsic effects, once again the question arises: why do the anti-corrosion coating systems –even to a very low percentage-fail? The result of that simplified study is that, in many cases the extrinsic properties of corrosion protection systems fail! In other words, hard is not always tough enough.

Innovative, Fully Amporphuos Viscous-Elastic Anti-Corrosion Material Based on Poly-Isobutene

This is the starting point of the idea to use viscous elastic material as innovative anti-corrosion system. The selection was based on the fact that the polymer should already contain a sufficient set of intrinsic properties. Poly-isobutene has proven to be the material of choice. The polymers of choice contain between 180 – 650 isobutene units in a polymer chain. There are only covalent bonds and the polymer just contains the elements hydrogen and carbon. The polymer chain cannot be cross-linked and will remain for the whole life-time as single polymer chains. This structure leads to an interesting effect: the cold flow. Even at very low temperature the poly-isobutene will over time, fill into all pores and structures of the substrates like steel, PE, PP, epoxy coated, de-rusted steel etc.

Macroscopic Properties of Poly-Isobutene Based Coatings

The material will permanently remain soft, tacky. At the same time, it will remain resistant against weathering, chemicals and stay impermeable for moisture, air and bacteria. These properties will be sustainable in the pipeline temperature range of -45 up to 120 degrees Celsius.

The adhesive strength of the material will be in the same range as the cohesive strength. Whenever you try to remove the coating in a wrap form, a certain portion of the coating material will always fully remain as a film on the surface of the metal pipe substrate.

The new viscous elastic coating provide end-users looking for pipeline rehab and new construction pipelines with: much stronger physical properties providing the end-user with longer investment, less maintenance and reduced costs over time, reduced instance of damage during service due to self-healing properties, highest levels of corrosion resistance, higher levels of chemical resistance, higher process temperature ranges, faster and easier application and installation without need for special equipment and operator skills (even at freezing conditions), better field joining methods and above all lower surface preparation and application costs.

How Coatings Based on Poly-Isobutene Work in the Field

Let us consider how the intrinsic corrosion protection properties work in the field. The surface preparation of the metal pipes is very simple. Make sure that the substrate is clean and dry. Marginal surface cleanliness is required. The minimal surface cleanliness (St 2/3 clean and dry) as approved by Shell Global Solutions B.V. and surface profile is not an issue while other systems may require near white metal finish (Sa-2-1/2) and a surface profile of at least 75 microns. There is also no necessity to use a primer such as 2 component epoxies. The application temperature starts at -30 C and can be extended up to + 50 C. This is not limited by the material, but by the working conditions of the applicators. Due to the fact that the material is soft and has very strong adhesive strength to the metal pipes, there is a “self-healing” effect. It is in the nature of the material that is non-toxic. The high adhesive strength ensure that no cathodic disbondment or under creep is possible. The adhesion remains permanent and starts immediately without any chemical reaction.

The new system does not require any waiting time before backfill after its application/installation while liquid coating requires at least one day to cure properly after application before backfilling. During the cold months, the waiting time for liquid coating to cure properly could take days. Obviously, it will be a decrease in cost for at least one day, which translates to elimination of the cost of manpower, equipment and utilities. As a result of no curing times, the time needed to perform the Rehabilitation work will be significantly less, making the cost of water drainage much less in return. Since the time of excavation until backfill requires water drainage to remove water from the bellhole (excavation), the drainage cost is significantly higher in the application of liquids because of the curing time. The application does not require costly equipment. It is installed manually in most cases. For liquid epoxy coating, tapes or shrinkable sleeves, equipment such as air compressor, spray equipment, air filters, tape machines, gas heater and manifolds are used.

Furthermore, these equipment and machines need maintenance and spare part replacement, that adds up to the cost. The application does not require highly skilled manpower.

This means that with little training on the job, the job can be done. This mostly also implies the benefit of lower labor cost. Holiday tests are normally not needed. The viscous-elastic anti-corrosion material is delivered as prefab in 2mm thickness, and repair is rare because it is easy to apply and defects are not expected application. During the application, there is no need to test for relative humidity, dew point and ambient temperature. Just make sure that the surface is clean and dry.

Acceptance and Outlook of the New Technology

The viscous elastic coating has been utilised in pipeline rehab and field joint projects worldwide and is widely specified by many major oil and gas companies. It is not an unusual situation with new technologies that it takes time to be adopted. As a period of time from development to acceptance is a standard obstacle typical to most industries. Several obstacles have limited the wide acceptance of this technology so far. The main obstacles are lack of norms enabling to compare the viscous elastic coating, cost effectiveness of the systems compared to traditional coatings and resistance to the new technology by companies delivering traditional coatings.

Several international coating standards have been published for field joint coatings such as heat shrink sleeves and tapes but they do not cover the specific material and corrosion protective properties of the viscous-elastic coating system.

The principal obstacles have been overcome. Amorphous viscous-elastic coatings will be added (amendment) to the new ISO field joint coating norm to be published in 2009: ISO 21809-3. The cost is currently extremely attractive to end-users when compared to traditional coating systems. Due to the trend of outsourcing technical control and inspection by major companies and the lately field repair costs, demand for failure proof systems is high. And resistance from competing products is being eroded by a growing acceptance by end-users.

Latest Field Joint Application

Field joint coatings have become an important but sometimes weak link in the corrosion protection of pipelines. Heat shrinkable sleeves are now the industry standard and have been used successfully but have also caused specific problems. The success of shrink sleeve technology relies on many factors such as surface cleanliness, pipe and sleeve temperature, adhesion to the factory coating. All these parameters depend largely, if not completely on the operator’s skill and experience. Improvements have been made in time by using epoxy primers but in some circumstances, e.g. in cold climates, good application is still difficult.

Once a shrink sleeve fails to adhere for 100%, or looses adhesion in time due to soil stress there is a risk of moisture penetrating under the sleeve, causing corrosion. The minor leaks will in time pass enough water to cause corrosion, but have a high resistance for cathodic protection current. Therefore, cathodic protection will not be able to protect the steel under the disbonded sleeve and the established survey methods (CIPS/DCVG) will not be able to detect the anomaly as a serious threat to the pipeline.

A new system has been introduced that combines the (mechanical) strength of a shrink sleeve with the well known viscous-elastic anti-corrosion properties**.** In this system the functions of corrosion protection and mechanical stability are separated and the quality of each of these functional components can be checked separately. A 2 mm layer of the viscous elastic wrappingband is applied on the field joint area; it adheres to all substrates without pre-tensioning. The cold flow technique makes the material flow into the smallest pores, even in cold climates. Once applied, it will remain elastic and will not disbond. After the application, the system is 100% holiday tested using 15 kV to ensure a flaw-free corrosion protection which can be guaranteed for 30 years.

After the satisfactory application of the anti-corrosion layer, a 2 mm Shrink sleeve is applied for mechanical stability. Although the shrink technique is the same, the application is easier and less critical. The pipeline does not require pre-heating and the first layer acts as a thermal insulator allowing a consistent and uniform shrinking process. In cold climates, the slight heat input enhances the micro flow of the anti-corrosion layer.

The adhesion of the shrink sleeve to the factory coating is important for the mechanical stability of the system; however, if the sealing is not 100% and water might penetrate under the sleeve, the viscous elastic layer will continue to provide full protection. Cathodic protection under the sleeve is not necessary because of the impermeability of the first applied layer. Any micro organisms or SRB’s that might develop under the sleeve will not affect the pipe or anti-corrosion coating.

The extra material cost for this system is very reasonable higher per square meter, however, substantial savings are made on personnel and mobilization costs, e.g. on blasting equipment, blasting grit clean-up, induction heating equipment.

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